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STUDY OF EARTH ORBIT SIMULATION OF LUNAR ORBIT RENDEZVOUS

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
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PROJECT APOLLO

STUDY OF EARTH ORBIT SIMULATION OF LUNAR ORBIT RENDEZVOUS

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SUMMARY

An earth orbit flight to demonstrate lunar orbit rendezvous capabilities of the Apollo crew and systems is explored. The objectives are: (1) to provide for an early experiment on a Saturn C-IB; (2) to demonstrate crew and systems capabilities of Apollo prior to first lunar mission (under conditions from which the crew could be recovered in the event of failure); (3) to provide information on system and crew performance in rendezvous for design improvement and crew training.

By proper choice of earth orbit altitudes an adequate simulation of the LEM rendezvous flight path can be obtained. The simulation is performed in less time (at least 22 percent) with greater terminal velocity (at least 45 percent) which means that the simulation would be slightly more stringent than the LEM rendezvous on both guidance techniques and crew capability. Thus, this simulation would provide a realistic assessment of the LEM rendezvous guidance.

INTRODUCTION

Success of the Apollo Lunar Landing Mission depends on the rendezvous of the LEM with the CM in lunar orbit. A thorough assessment of the proposed guidance techniques and equipment as well as crew capabilities is therefore in order. Fixed based simulation with tie-ins to guidance and control hardware proposed for the rendezvous maneuver will provide part of this assessment. However, a demonstration of the maneuver in earth orbit appears feasible and would provide a flight test environment where recovery of the crew can still be accomplished in the event of a malfunction. Such a demonstration could provide confidence in the rendezvous equipment and procedures.

Specifically, the earth orbit rendezvous could accomplish several objectives; namely, it would subject the crew and guidance equipment to realistic environment conditions of space; it would provide for a true assessment of guidance techniques and equipment as well as crew capabilities; it could serve as a means for training crews to perform rendezvous maneuvers; and it would demonstrate the ability to perform lunar orbit rendezvous prior to the first manned lunar mission. The purpose of this memorandum is to present the results of a brief investigation of an earth orbit simulation of the LEM lunar orbit rendezvous.

TRAJECTORY SIMULATION

The problem of rendezvous is essentially the same regardless of the central body (earth, moon, sun, et cetera) about which the maneuver is being performed. The only differences lie in the magnitudes of the orbital parameters (speeds, distances, periods, et cetera). However, the rendezvous problem is not concerned with inertial speed and range, but instead, is concerned with the relative speed and range between the two orbiting vehicles. Therefore, even though the orbital speeds and ranges of rendezvous vehicles may differ considerably from one central body to another, it still may be possible to find rendezvous trajectories about different central bodies which are quite similar. With this in mind, calculations were made to determine if such a similarity could be found between LEM trajectories about the moon and a simulated LEM in orbit about the earth.

In figure 1 are shown the trajectories for the entire LEM mission as viewed from the CM in a circular orbit 80 n. mi. above the lunar surface. The Hohmann transfer for normal launch and the abort intercept trajectories (including the equiperiod trajectory) all represent possible LEM intercept and rendezvous trajectories.

In the earth orbit simulation of these trajectories, the minimum circular orbit altitude was chosen as 100 n. mi. since orbit lifetimes for altitudes less than this are too short. Having established the lower altitude, a range of altitudes was investigated to determine what circular target orbit altitude would yield rendezvous trajectories which closely approximate the LEM intercept transfer trajectories. It was found that an altitude of 180 n. mi. for the target yielded a good approximation to the Hohmann transfer for the normal launch; hence, this altitude was chosen for the target orbit. A comparison of the simulated and true LEM trajectories is shown in figure 2. The simulations for the abort transfers (from 5,000 ft. and 22,000 ft.) were obtained by adjusting the apogee altitude until the flight path approximated as closely as possible the true abort transfers. For the simulation of the equiperiod transfer, the apogee altitude was fixed by the period of the target orbit and could not be adjusted to approximate the true flight path; hence, the simulation for the equiperiod transfer is not as good as for the other transfers. However, the descent and rendezvous portions of the equiperiod transfer are simulated very closely. In summary, the results shown in figure 2 indicate that the flight path simulation is adequate; therefore, any visual and/or radar acquision techniques could be checked out under realistic conditions, including sun, star, dark body, and bright body backgrounds.

Approximation of the LEM flight path was the prime concern in this simulation, however, the range of closing velocities and transfer times is also of concern. The closing velocities and transfer times of both the LEM trajectories and the simulations are listed in table 1 for comparison. It is evident from the table that the simulation requires less time (at least 22 percent) and greater closing velocities (at least 45 percent) than do the actual LEM transfers. This does not, however, detract from the simulation; in fact, this means that the simulation would be slightly more stringent than the LEM rendezvous, requiring the nulling of larger velocities and less time in which to perform the rendezvous.

SPACECRAFTS

There are two possible choices of spacecrafts with reentry capability which could be used in this simulation; the Gemini spacecraft or the Apollo CM. It would be most desirable to use the Apollo CM to simulate the LEM since much of the guidance equipment is the same for both spacecrafts; however, development time of this spacecraft might cause the results of the simulation to be too late to aid the LEM design or astronaut training. For this reason, the Gemini spacecraft might be a better choice.

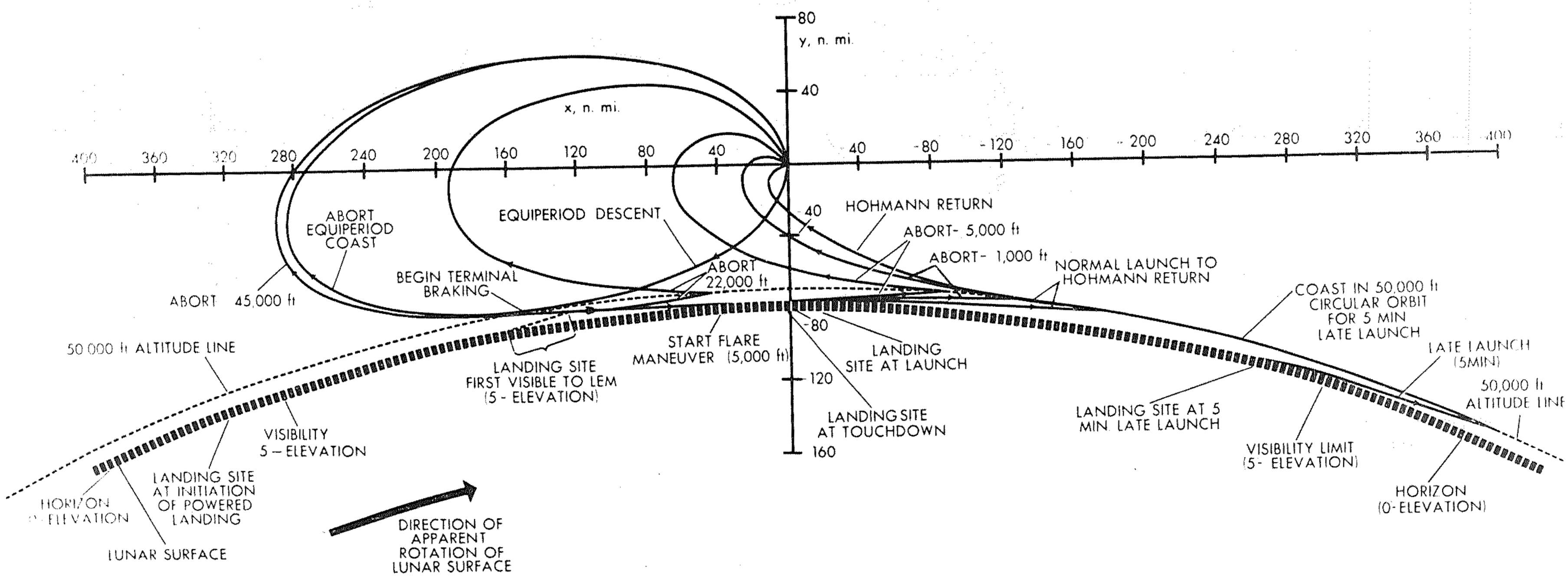
CONCLUDING REMARKS

In view of the critical nature of the LEM rendezvous maneuver, it appears desirable that an earth orbit rendezvous experiment be performed in order to provide a realistic simulation of the maneuver. It was shown that an adequate simulation of the LEM trajectories can be obtained by placing a spacecraft (either the Gemini or the Apollo CM) in a circular orbit 100 n. mi. above the surface of the earth and performing a rendezvous with a target in a 180 n. mi. circular orbit. Such a simulation would provide a realistic assessment of the guidance techniques and would demonstrate the ability to perform the critical lunar orbit rendezvous maneuver.

TABLE I.- TRAJECTORY TIMES AND CLOSING RATES

	Target Altitude	LEM Altitude	Time, min.				Closing Rate, fps			
			Hoh-mann	5,000' Abort	22,000' Abort	Equi-period	Hoh-mann	5,000' Abort	22,000' Abort	Equi-period
LEM Rendezvous	80 n.mi.	50,000 ft	58	76	87	93	97	199	293	373
Simulation	180 n.mi.	100 n.mi.	45	57	65	69	141	282	449	559

FIGURE 1 **LUNAR LANDING AND LAUNCH OPPERATIONS IN CM VISUAL AXIS SYSTEM 80 N MI EQUIPERIOD DESCENT**



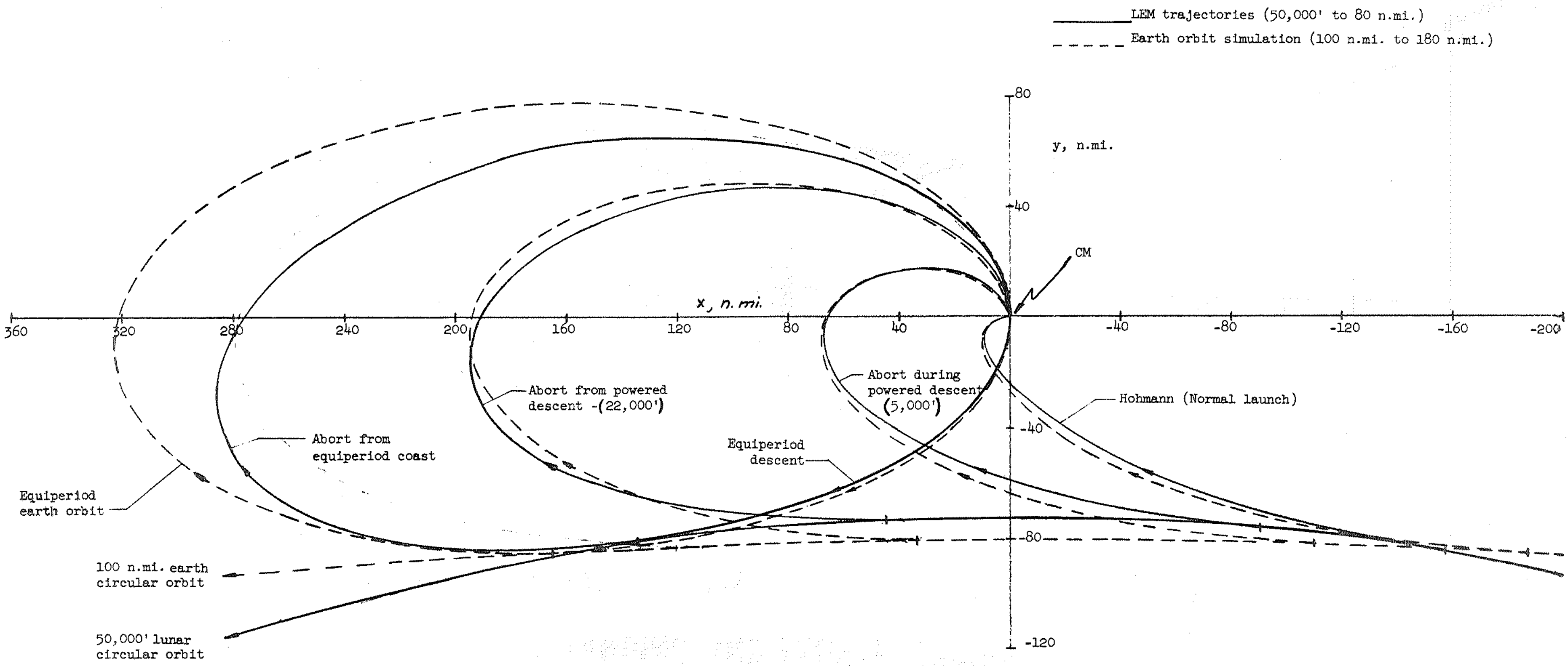


Figure 2. Comparison of rendezvous trajectories (CM rotating axes)